Recovering Hardware Injection Waveforms with Maximum Entropy

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Previous Work Using Maximum Entropy

- Study investigating recovery of core-collapse supernova waveforms with maximum entropy presented previously (see G050090-00-Z)
  - » Recovered Ott et al. waveform from simulated data
  - » Recovered waveform contained info on core bounce type and progenitor mass, angular momentum magnitude and angular momentum distribution
  - » Simulated data created with realistic detector response but same response function used to simulate data and recover waveform
  - » Simulated data created with white noise scaled to appropriate amplitudes

Remaining Questions

- Do we really know the instrument responses well enough to reconstruct signals using maximum entropy?
  - » Maximum entropy assumes perfect knowledge of response function.
- Can maximum entropy handle actual, very non-white, instrument noise?

Recovery of hardware injection waveforms would answer these questions.

Review of Maximum Entropy

- Maximum entropy attempts to find a signal *h* that minimizes the function

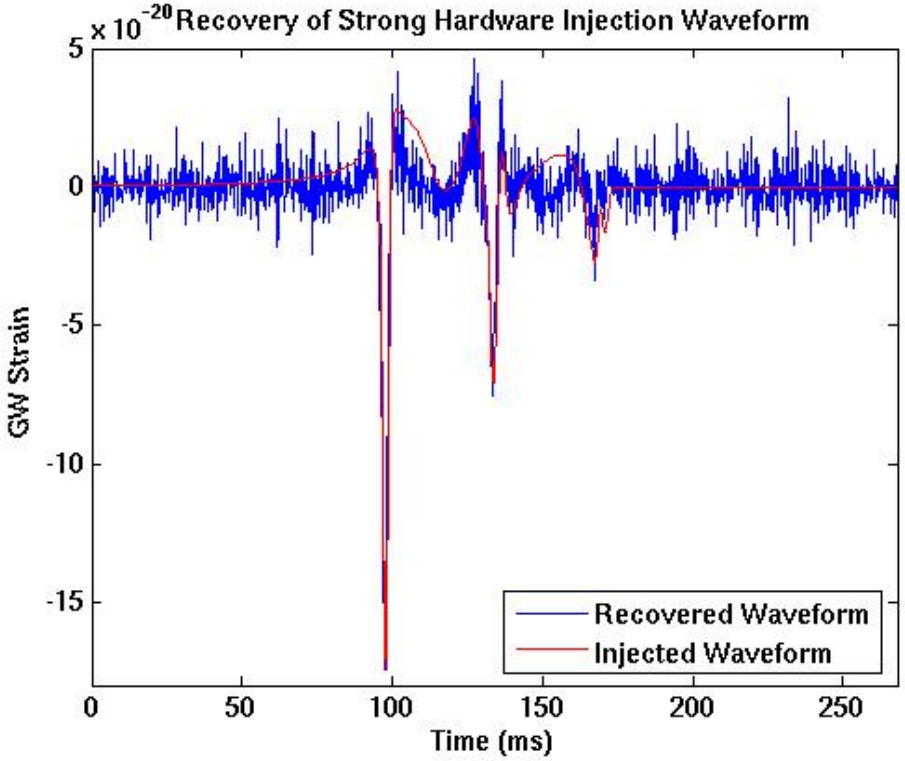
$$F = \frac{1}{2}\chi^2 - \alpha S$$

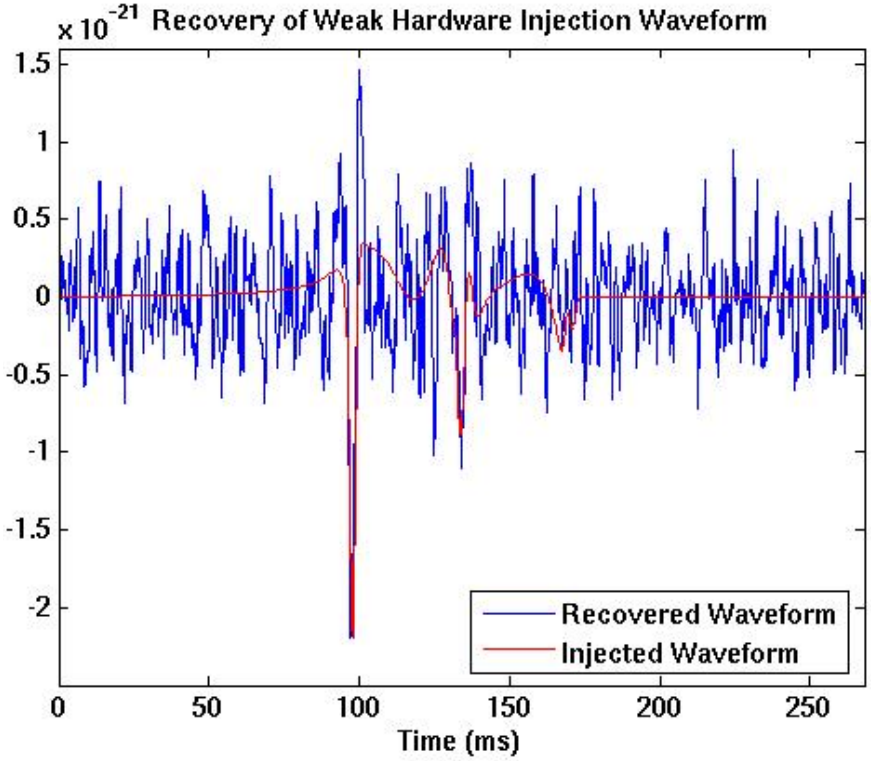
- Where $\chi^2 = (Rh - d)^T N^{-1} (Rh - d)$ ensures close fit with observed data.
  - » *R* = detector response, *d* = data, *N* = noise covariance
- *S* is a regularizer, equivalent to Shannon information entropy, that ensures smoothness and prevents overfitting
- Alpha is a Lagrange parameter that balances the two terms.

Hardware Injection Overview

- Attempted recovery of two hardware injections during S4 (795574893, 795574933)
  - » Present in all 3 LIGO IFOs
  - » Zwerger-Muller waveform A3B3G1
  - » Weakest and strongest of daily ZM injections (hrss = 0.5e-21, 8.0e-21)
- Recovery of both waveforms successful
- NOTE: H1, H2 injections have sign opposite original waveform

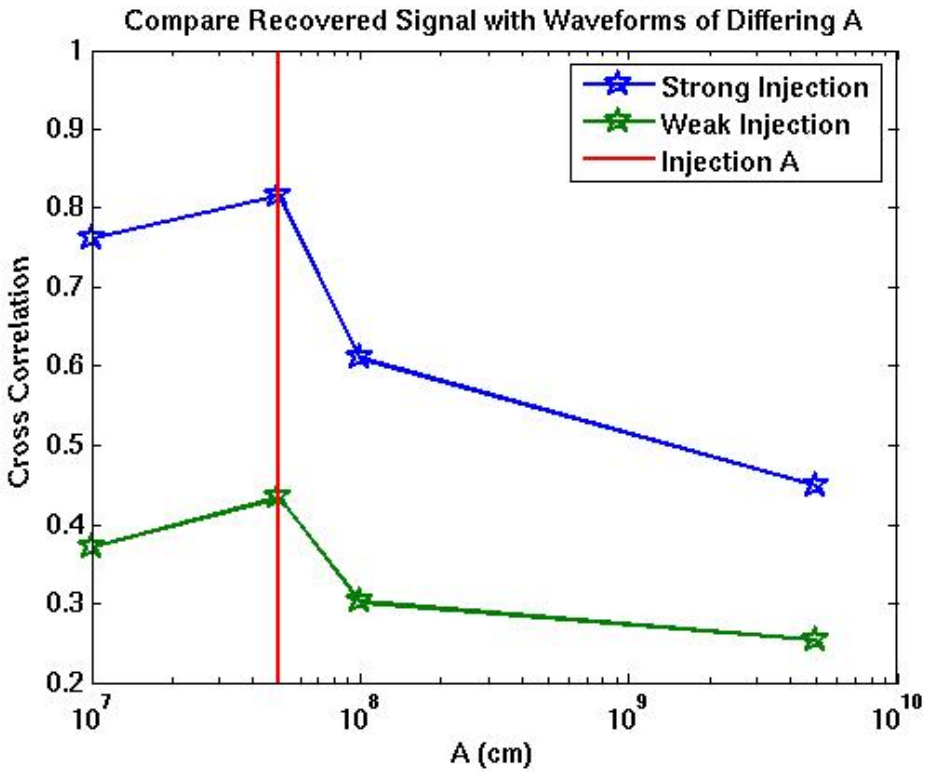
Waveform Recovery





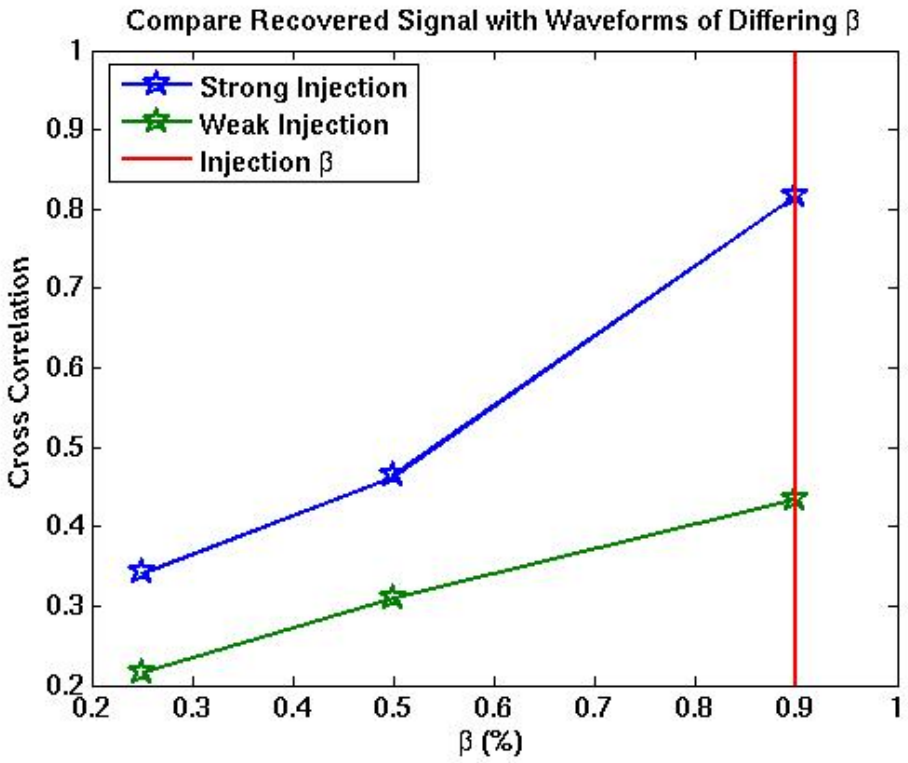
Progenitor Parameter Estimation

- Plot shows cross correlation between recovered waveform and waveforms that differ by A
- A = degree of initial differential rotation
- A = distance at which rotation drops to half that at center
- Recovered waveform has most in common with waveform of same A as injected signal



Progenitor Parameter Estimation

- Plot shows cross correlation between recovered waveform and waveforms that differ by beta
- beta = ratio of rotational energy to gravitational potential energy
- Recovered waveform has most in common with waveform of same beta as injected signal



Conclusions

- Hardware injection waveforms can be recovered via maximum entropy.
  - » Recovery good enough to retain source information carried by the wave.
- Maximum entropy method is capable of handling realistic data, noise.
- Current estimation of IFO responses is very good and completely sufficient for maximum entropy